

FIG. 1

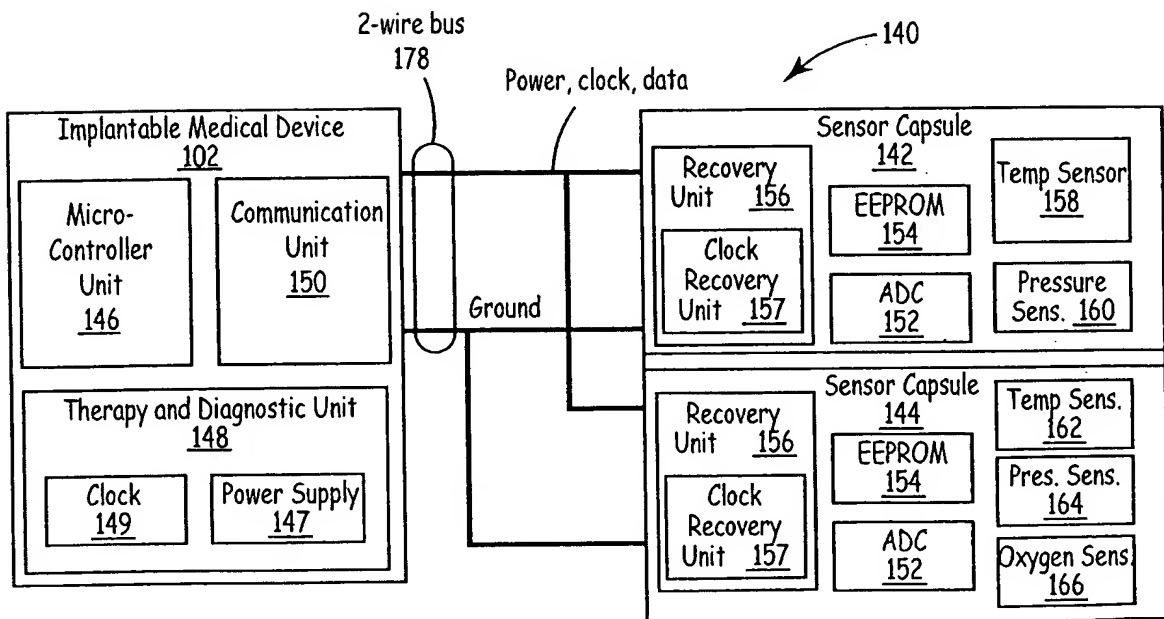


FIG. 2

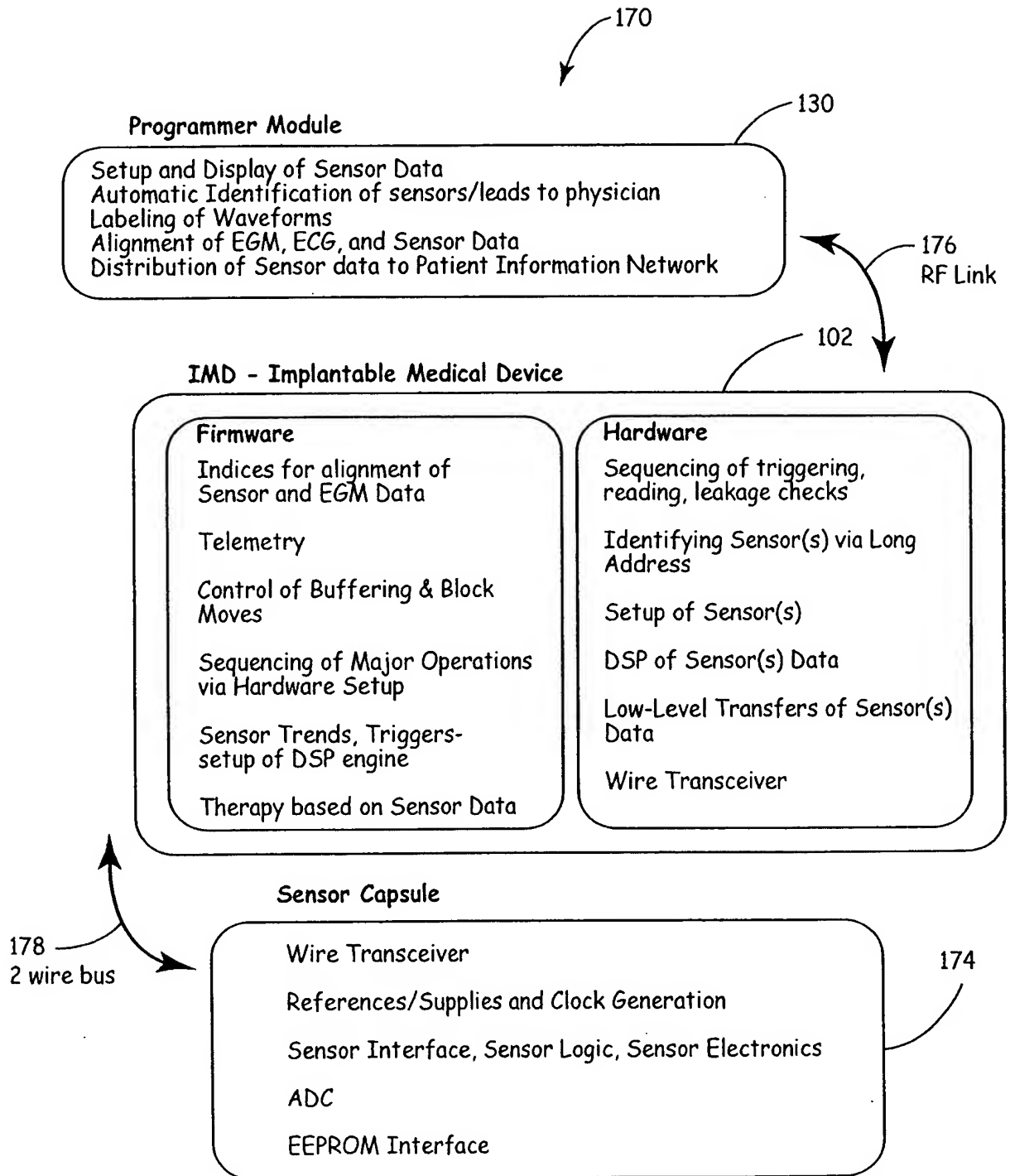


FIG. 3

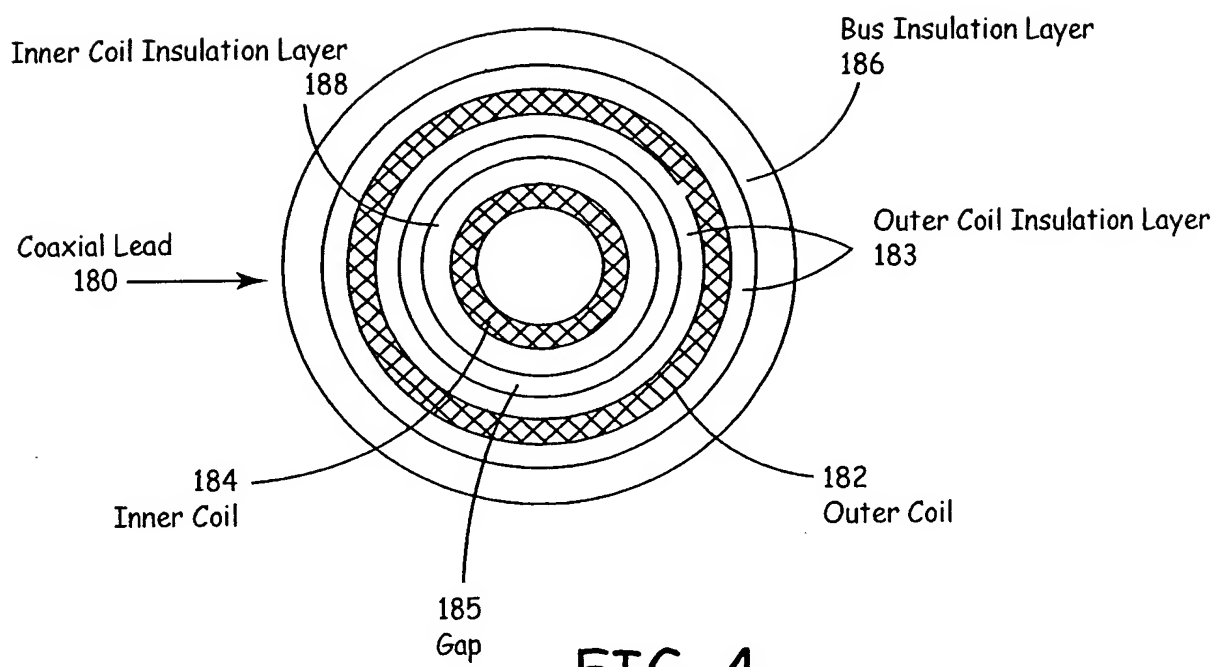


FIG. 4

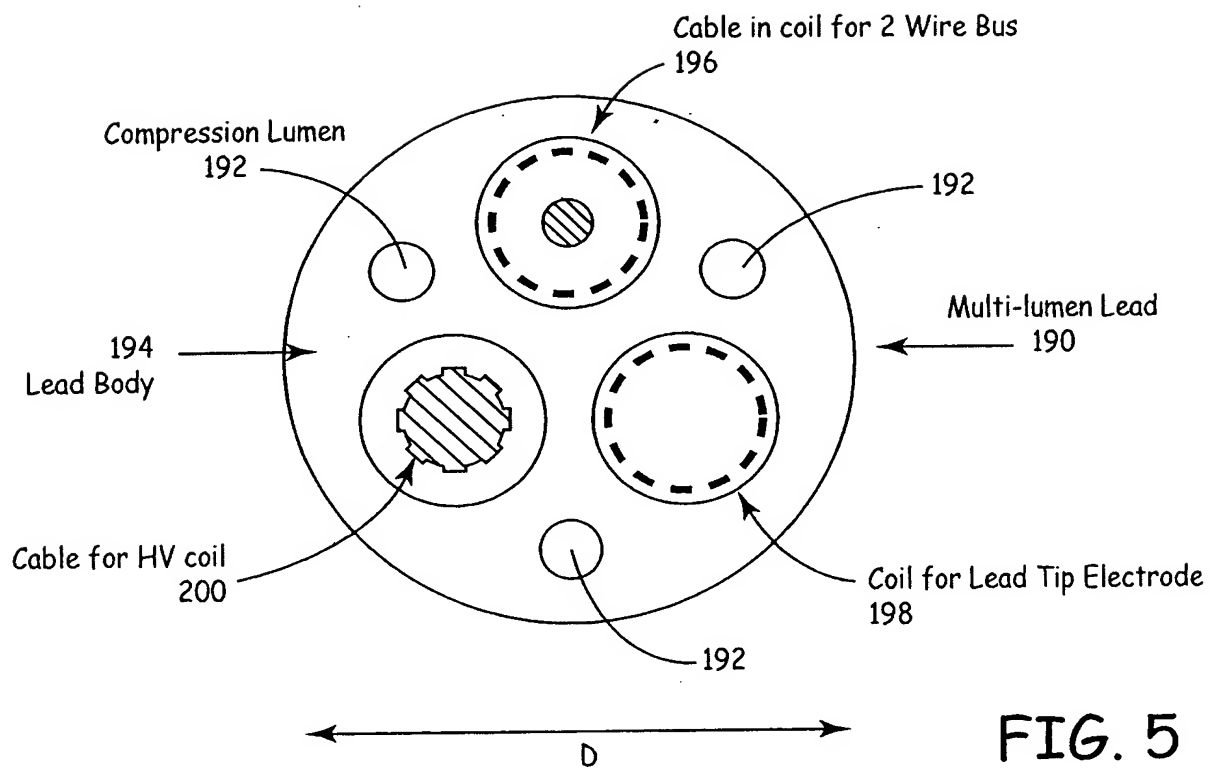


FIG. 5

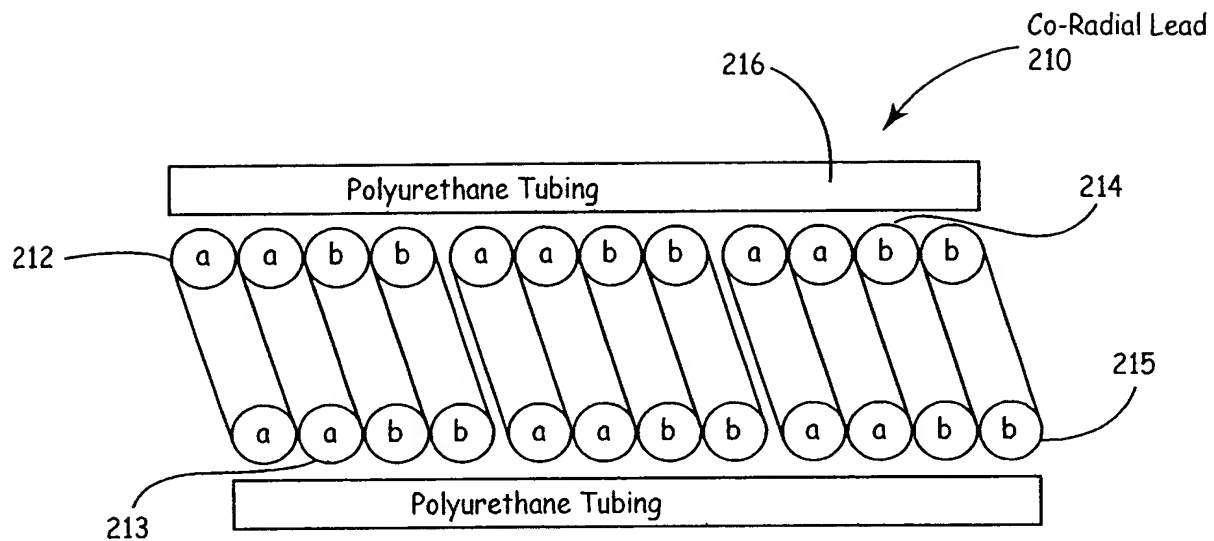


FIG. 6

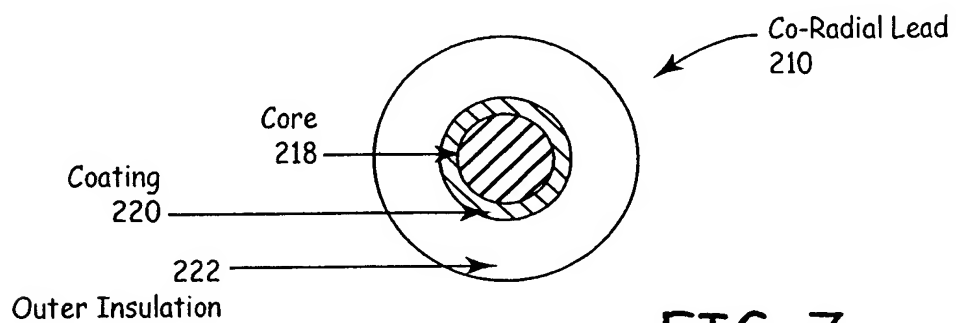


FIG. 7

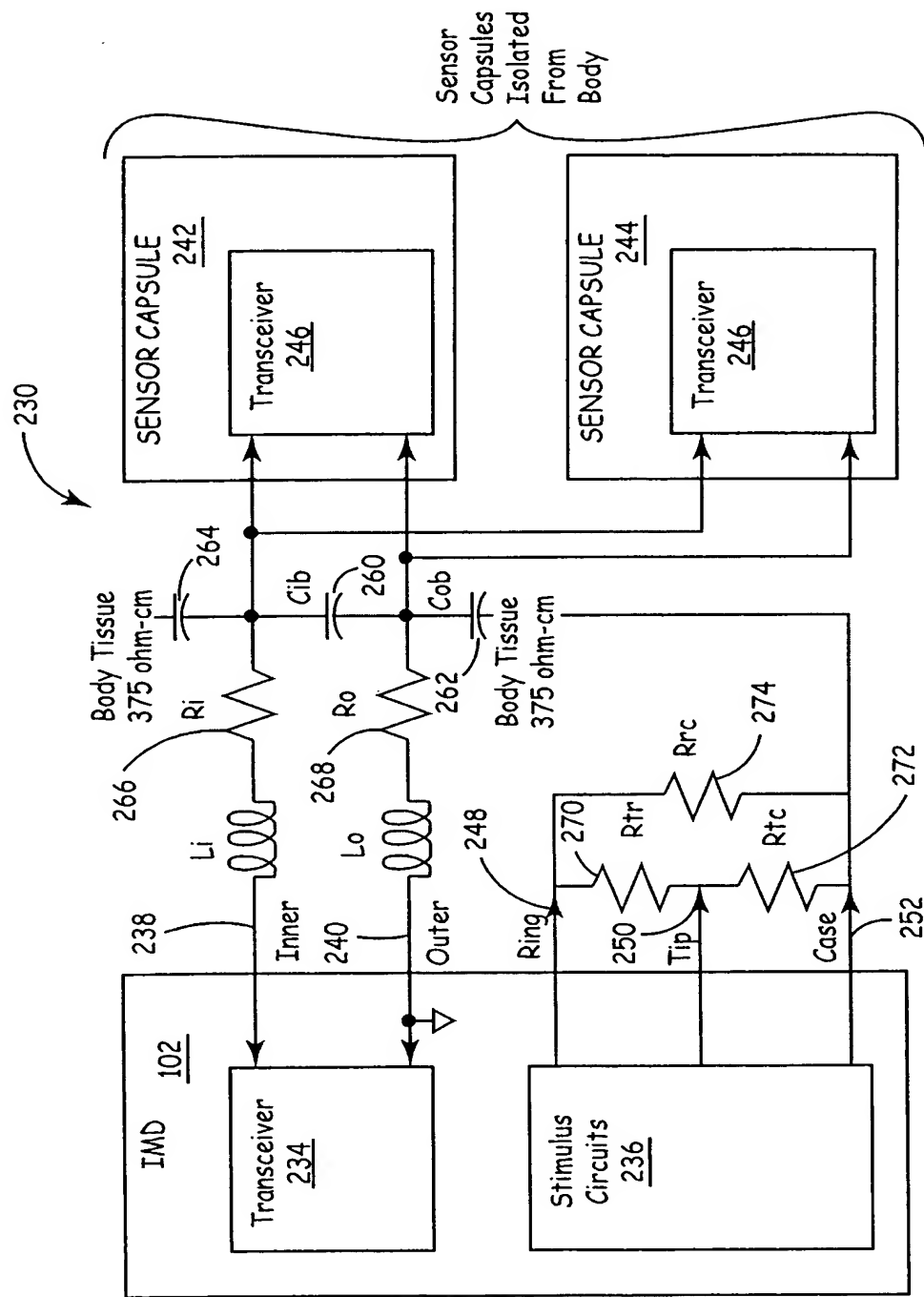


FIG. 8

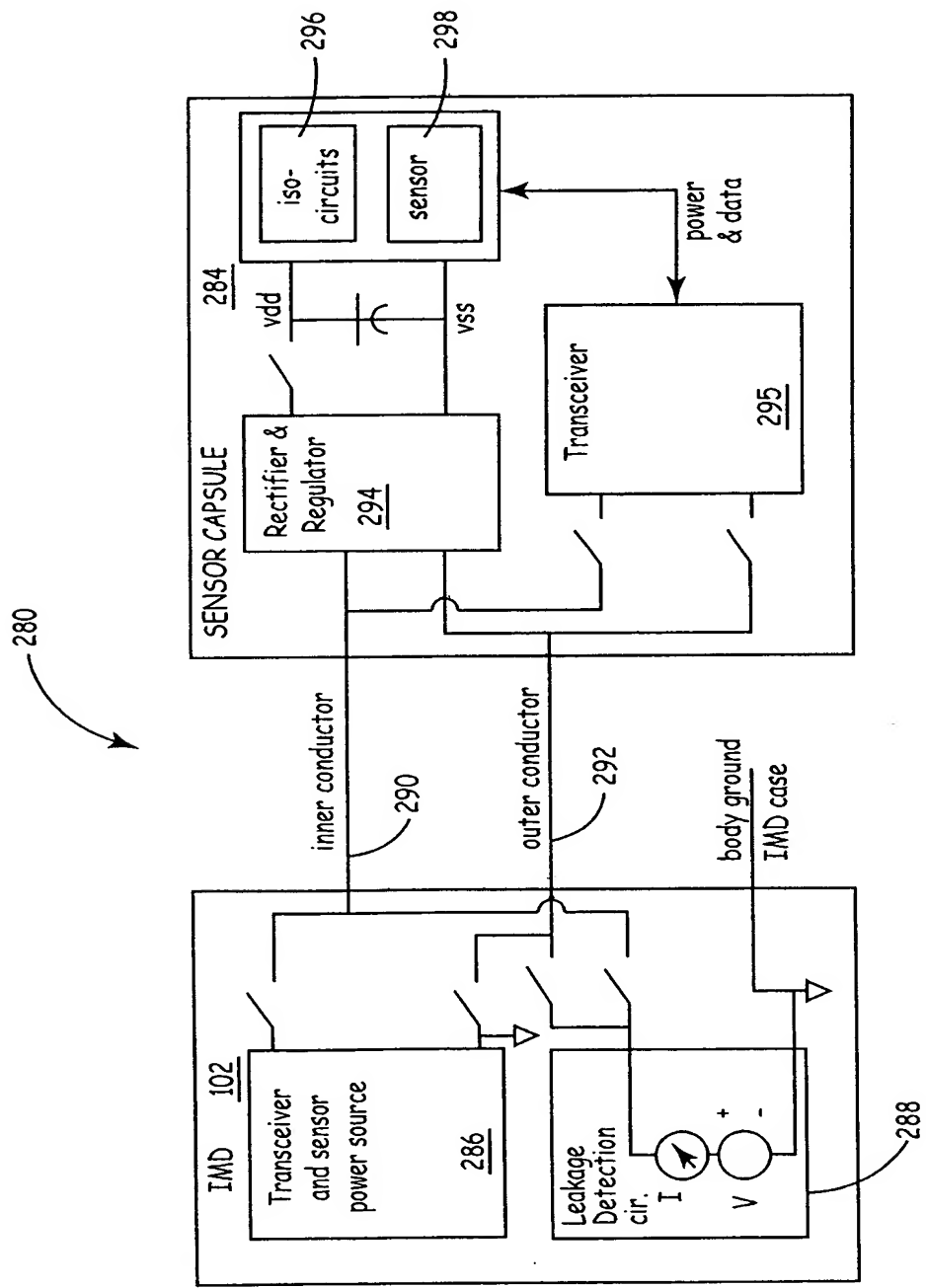


FIG. 9

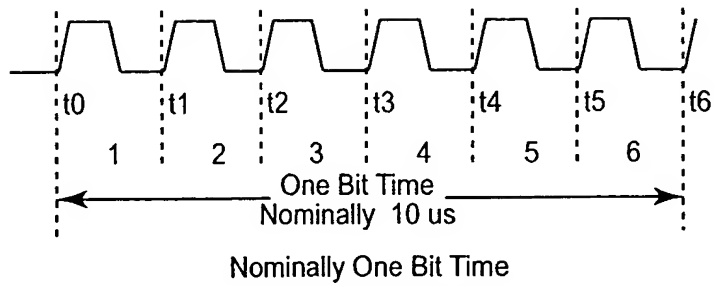


FIG. 10

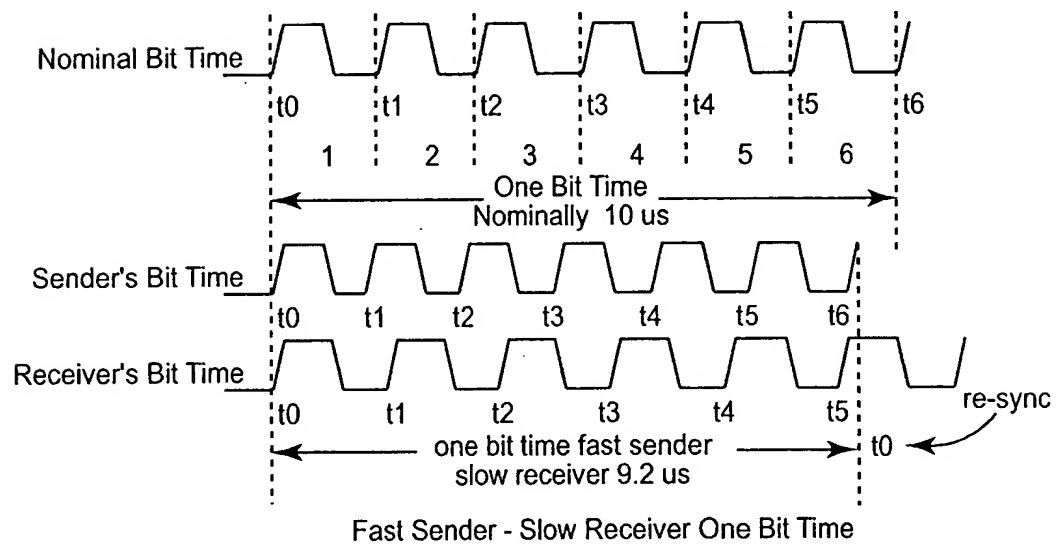


FIG. 11

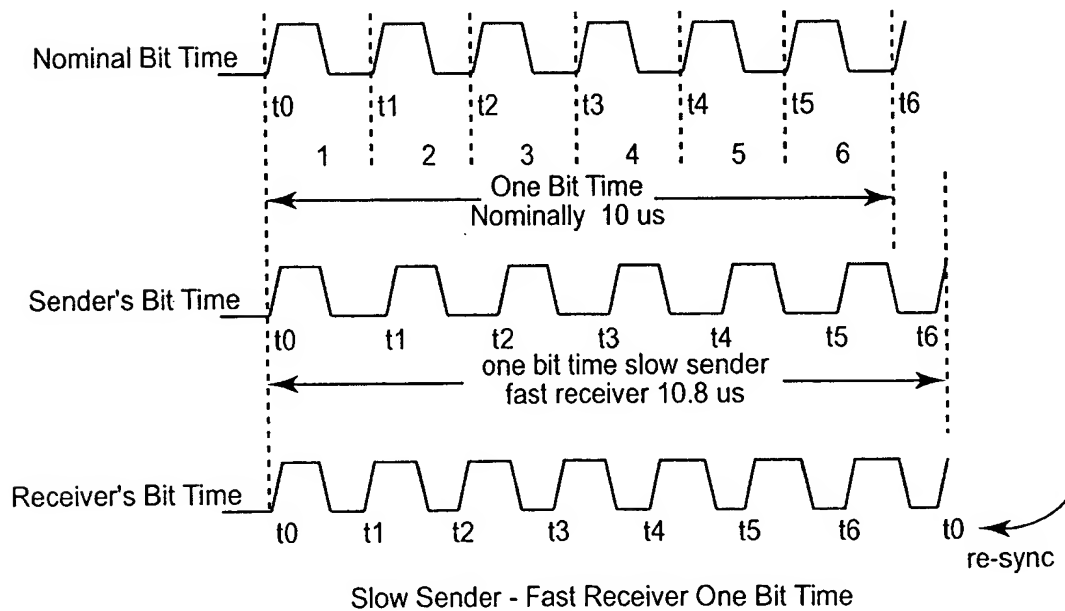


FIG. 12

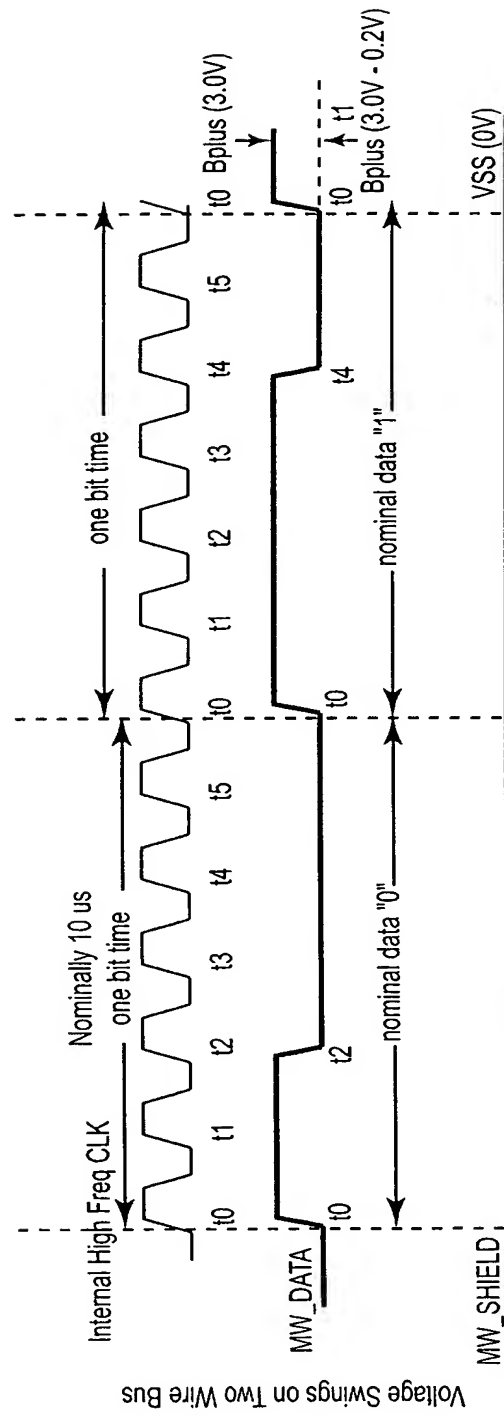
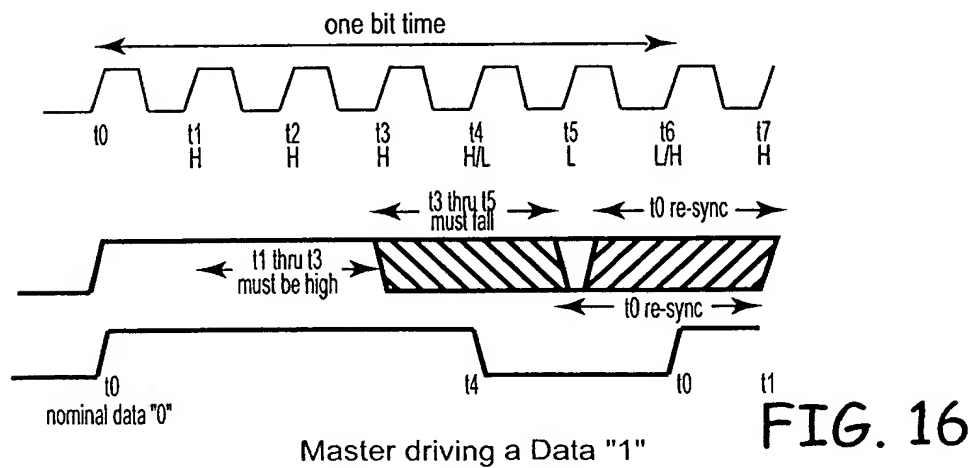
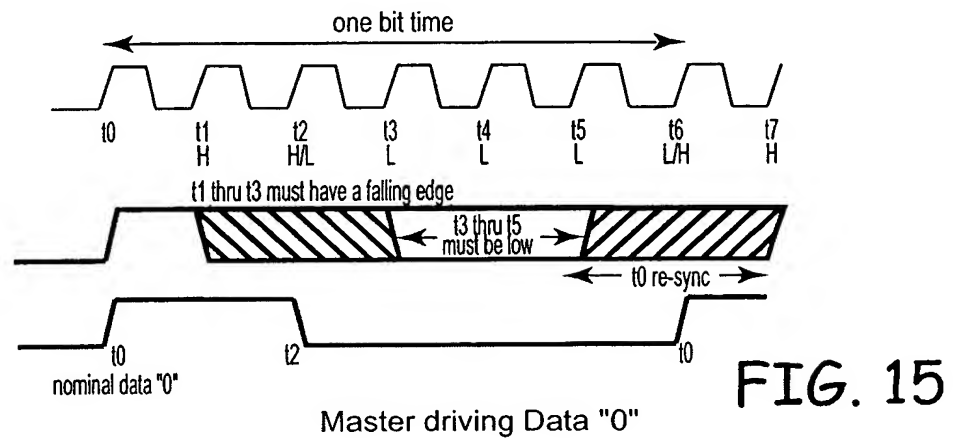
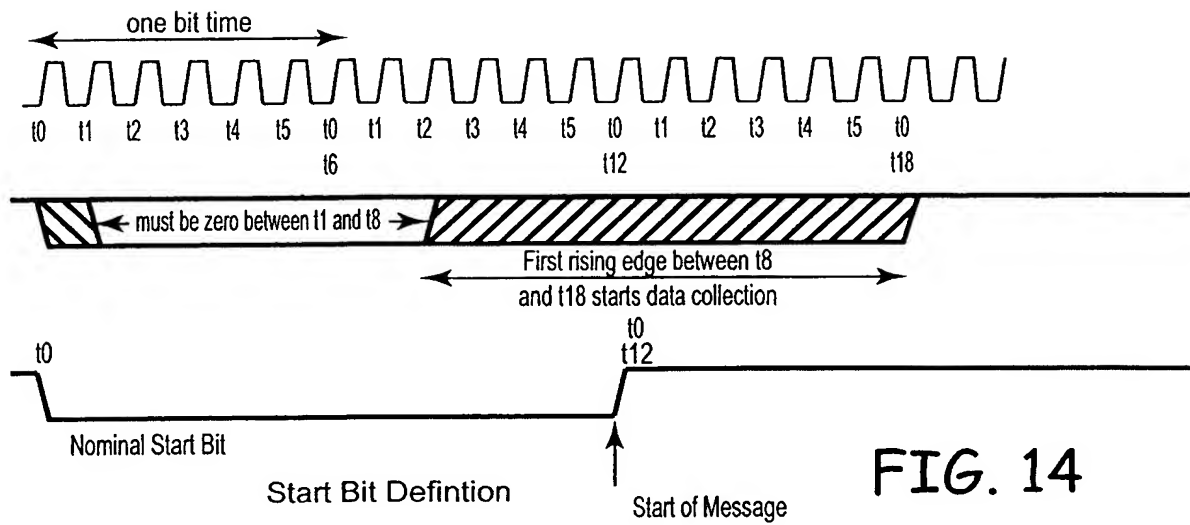


FIG. 13



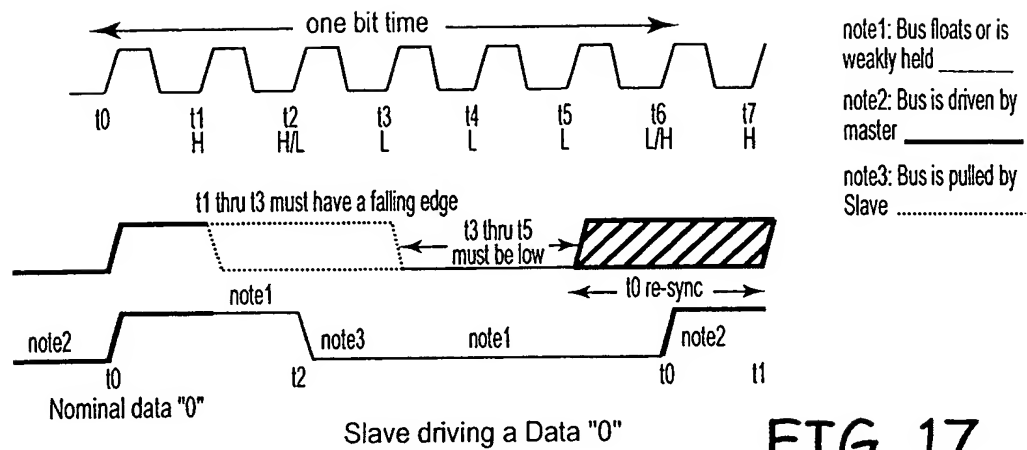


FIG. 17

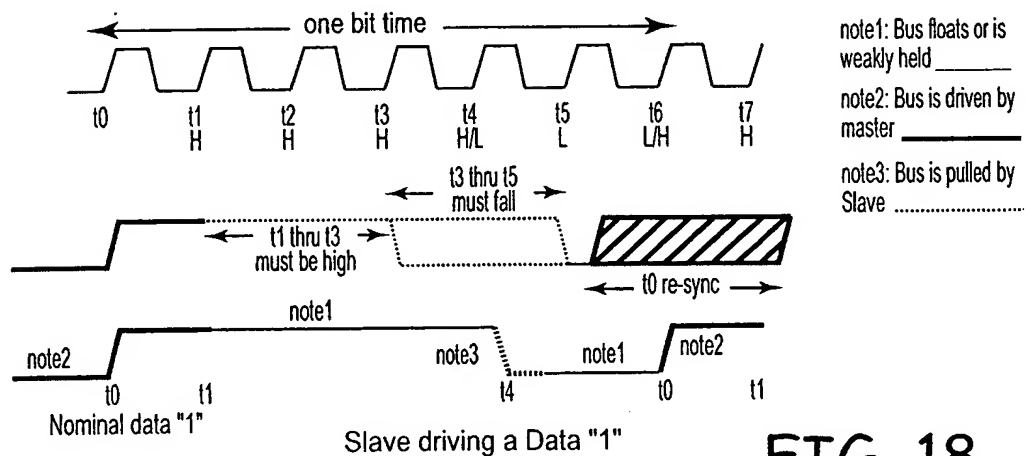


FIG. 18

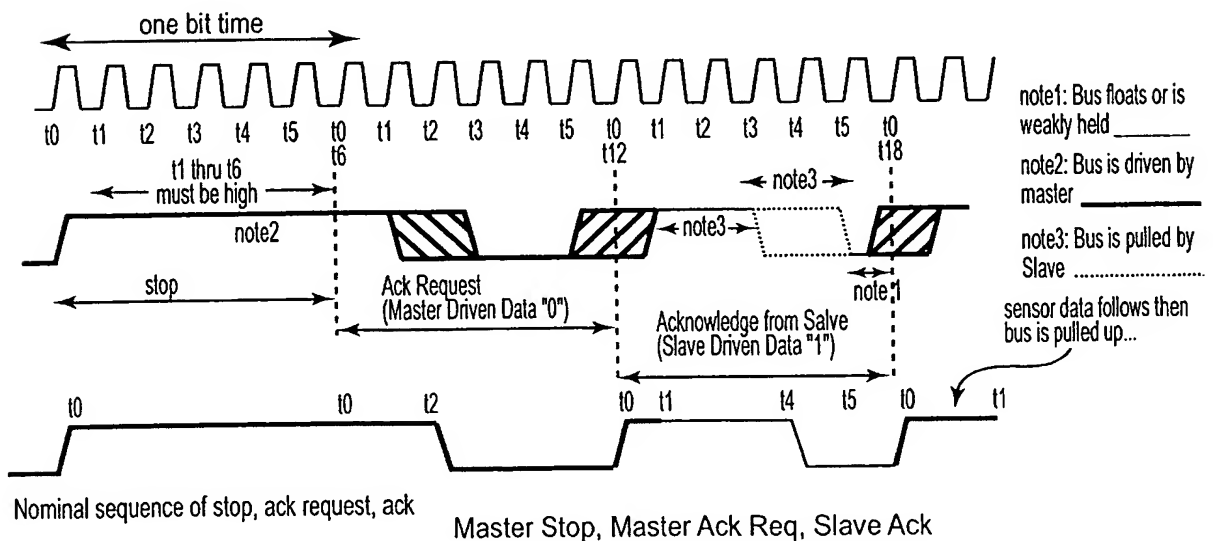
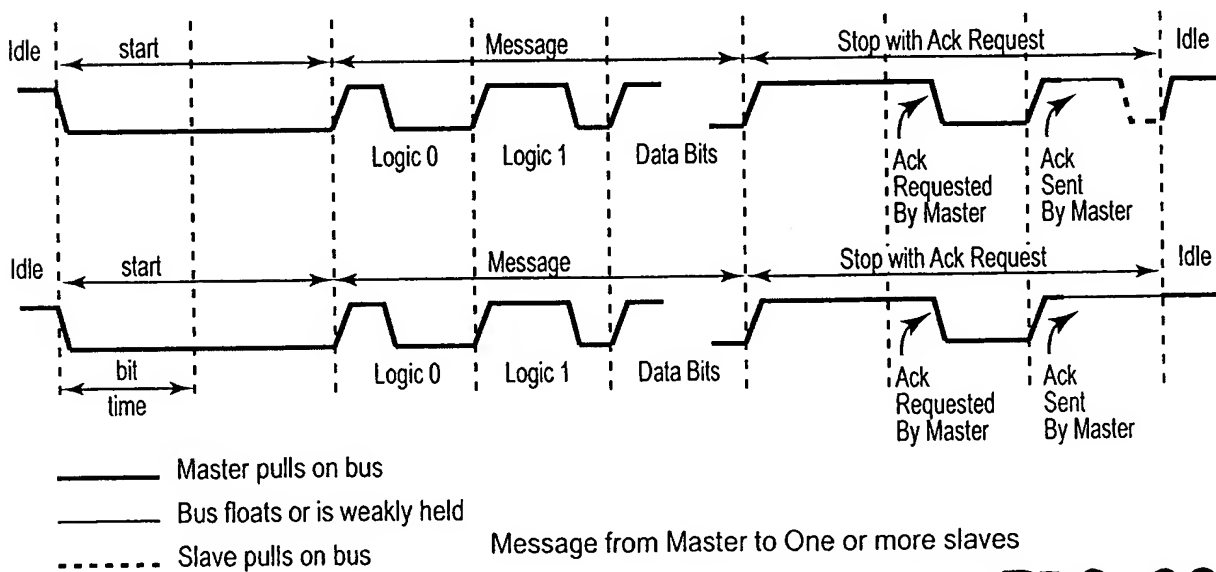
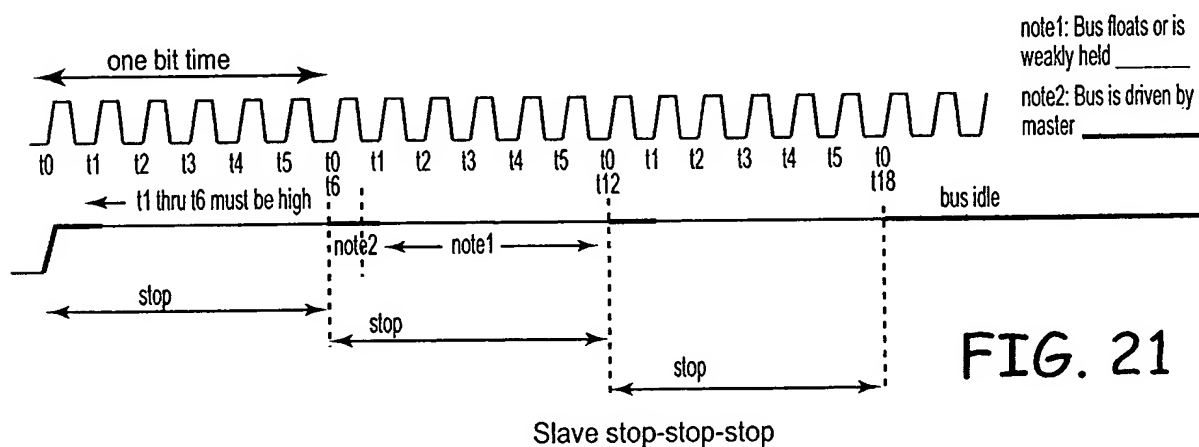
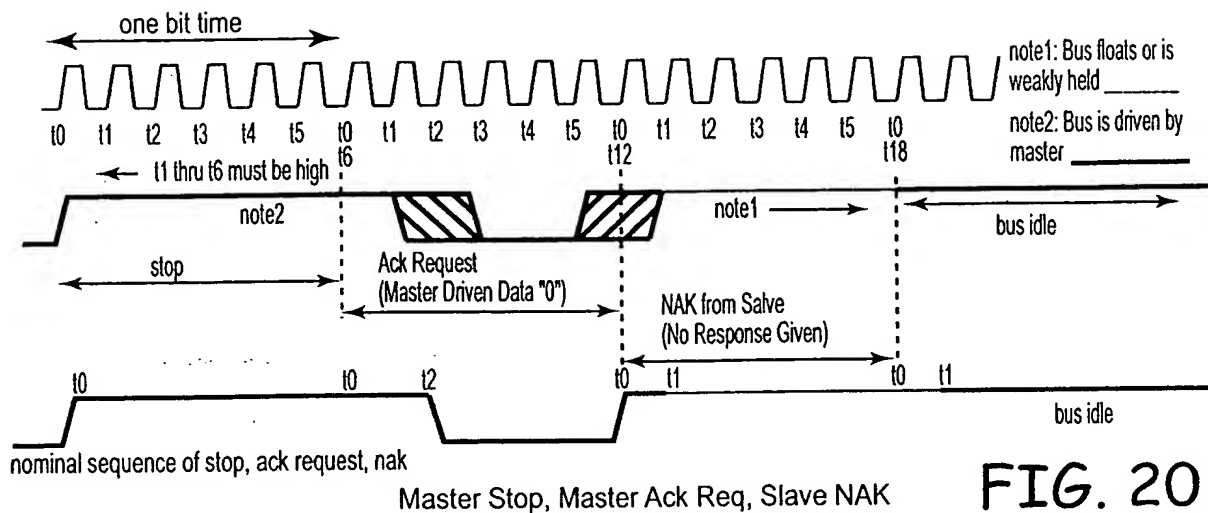
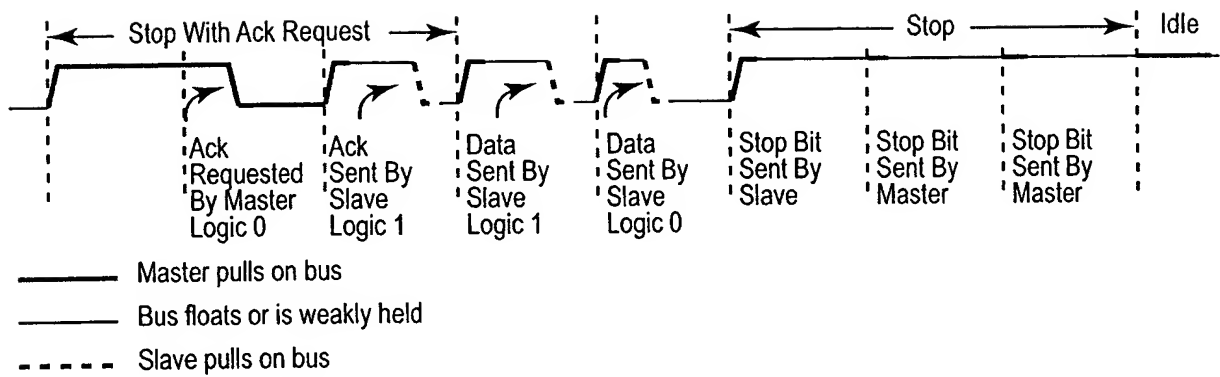


FIG. 19





A response with data from slave to master

FIG. 23

General Command Format

	msb...lsb	one bit	msb...lsb	msb...lsb	msb...lsb	Stop-AckReq-(N)Ack	
Master1	Master2	M3	Master4	Master5	Master6	Master7	Total Bit Times
Start	Slave(s)	QT	Master Command Name	Data	FCS	Stop Sequence	
2 bit times	6 bit times	1 bit time	5 bit times for most commands	8 bit times for most commands	8 bit times	3 bit times	33 for most Commands
	G ₁ G ₀ A ₃ A ₂ A ₁ A ₀						

FIG. 24

Long Address Format

64 bit Long Address					
msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb
6 Bit Manufacturer Code (up to 64 Manufacturers) 00000 ₂ = Medtronic 00001 ₂ = Viatron 00010 ₂ = MRG	6 bit Protocol Version (Each manufacturer can have up to 64 different protocols)	21 bit Slave Model ID	20 bit Slave Serial Number (up to 1,048,576 unique slaves)	7 bit Manufacturing Facility (Manufacturer Specific) ASCII Char V = Medtronic Villalba Puerto Rico ASCII Char R = Medtronic Rice Creek	4 bit Slave Number (one lead could have 16 slaves) (allows numbering of the slaves on the lead)

FIG. 25

Slave Short Addresses and Multicast Examples

Slave Short Address	Master2					
	Slave(s)					
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀
0	0	0	0	0	0	1
1	0	0	0	0	1	0
2	0	0	0	1	0	0
3	0	0	1	0	0	0
4	0	1	0	0	0	1
5	0	1	0	0	1	0
6	0	1	0	1	0	0
7	0	1	1	0	0	0
8	1	0	0	0	0	1
9	1	0	0	0	1	0
A	1	0	0	1	0	0
B	1	0	1	0	0	0
C	1	1	0	0	0	1
D	1	1	0	0	1	0
E	1	1	0	1	0	0
F	1	1	1	0	0	0
Broadcast All	0	0	0	0	0	0
Multicast Slaves: 3.2.1.0	0	0	1	1	1	1
Multicast Slaves: 7.5.4	0	1	1	0	1	1
Multicast Slaves: B.A.8	1	0	1	1	0	1
Multicast Slaves: E.D.C	1	1	0	1	1	1

FIG. 26

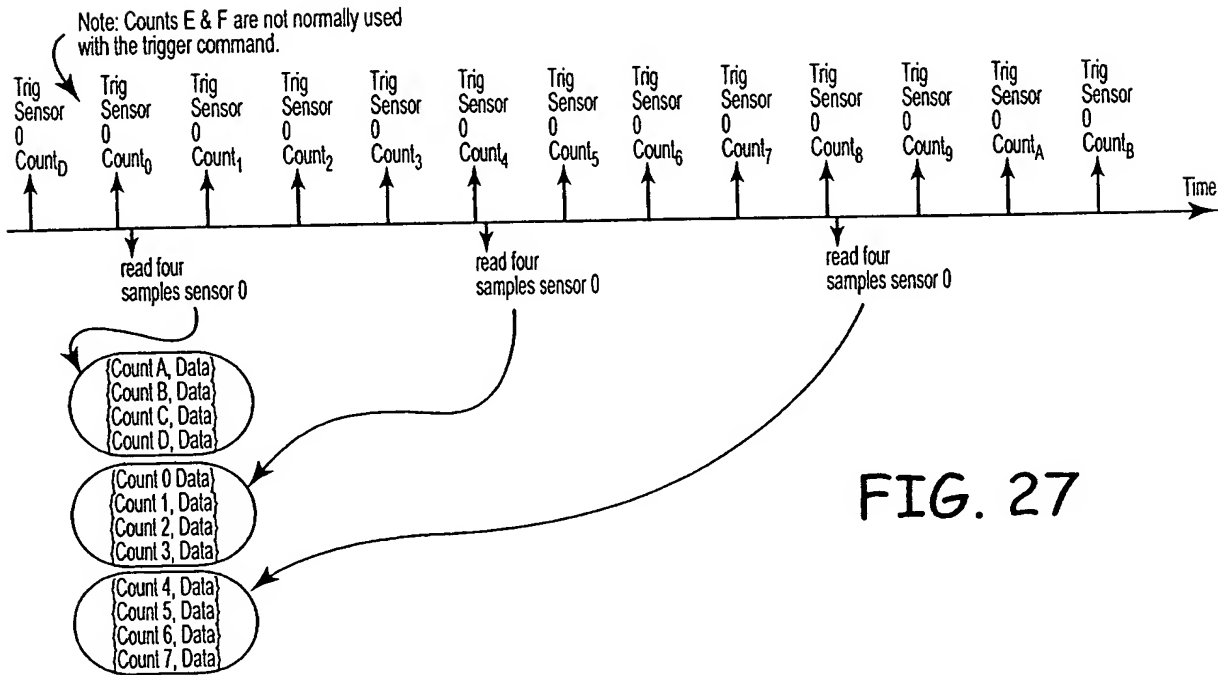
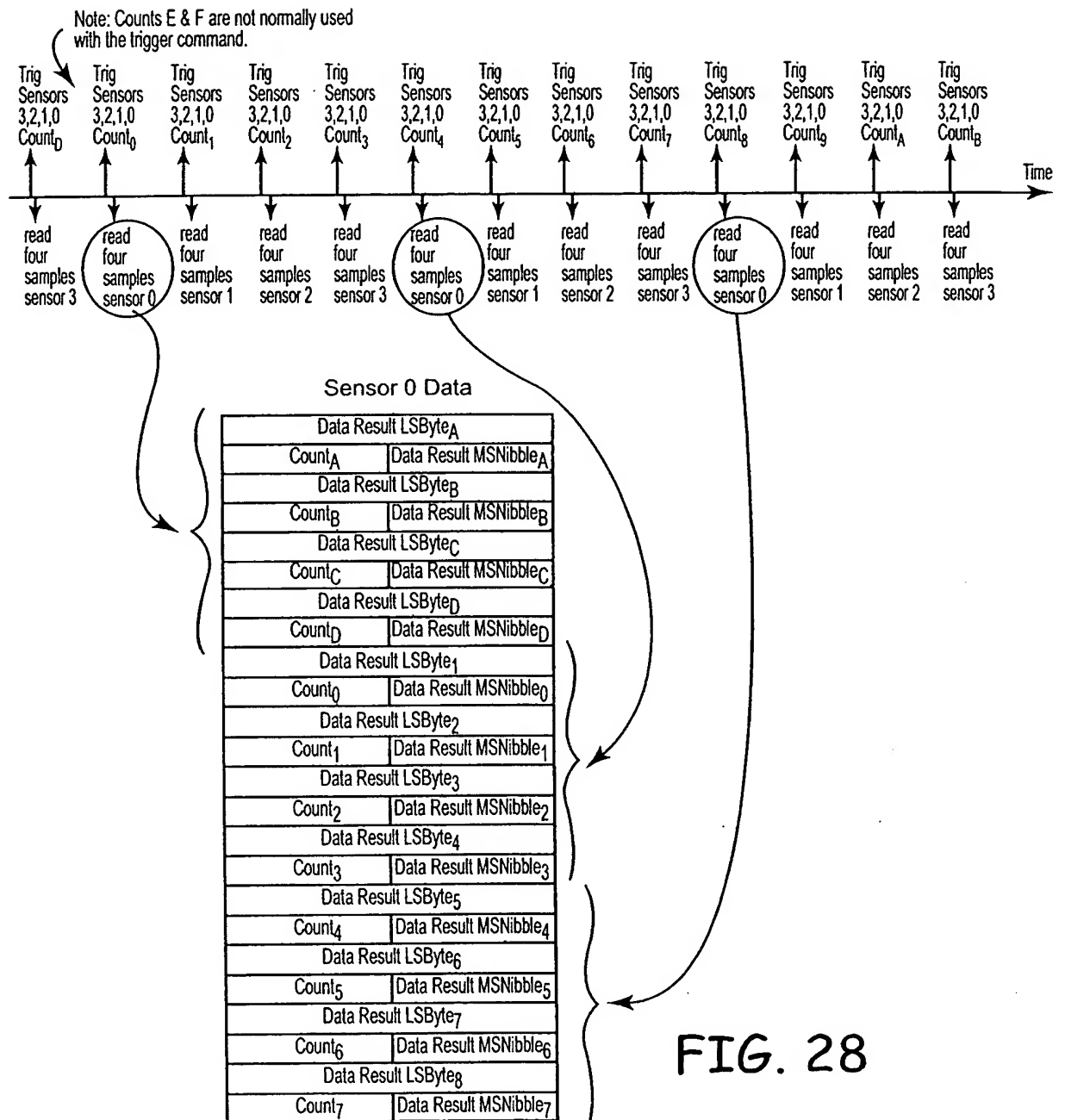


FIG. 27



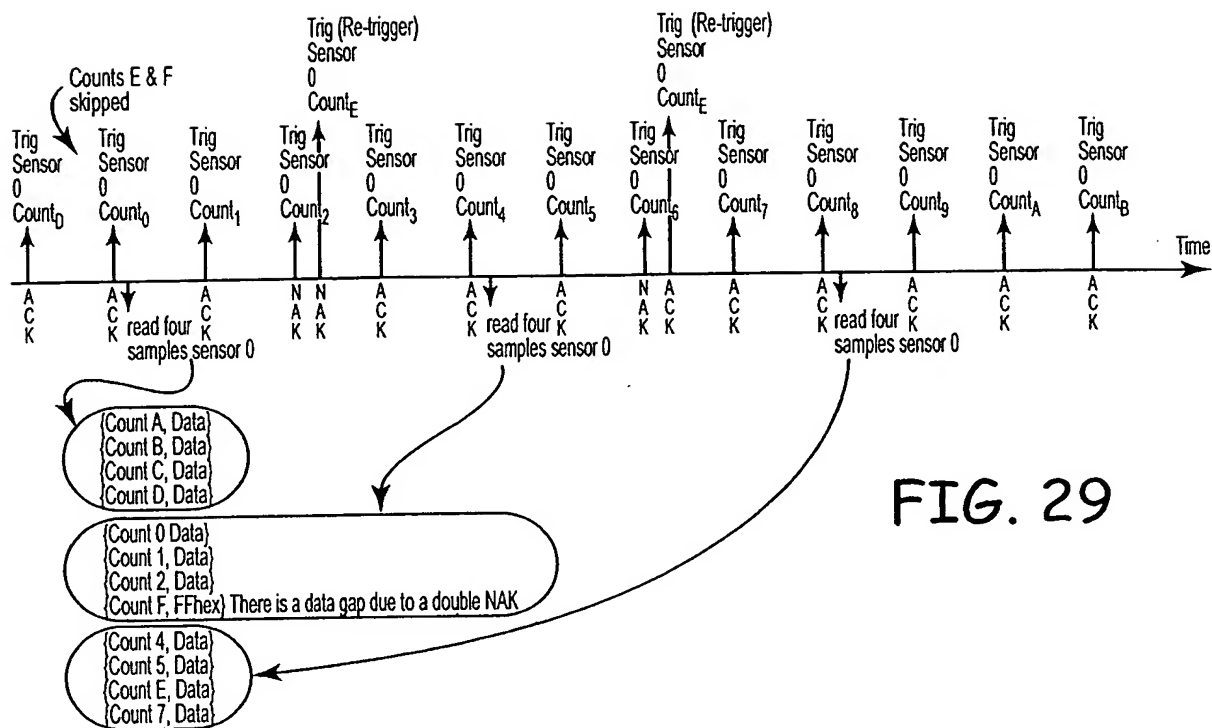


FIG. 29

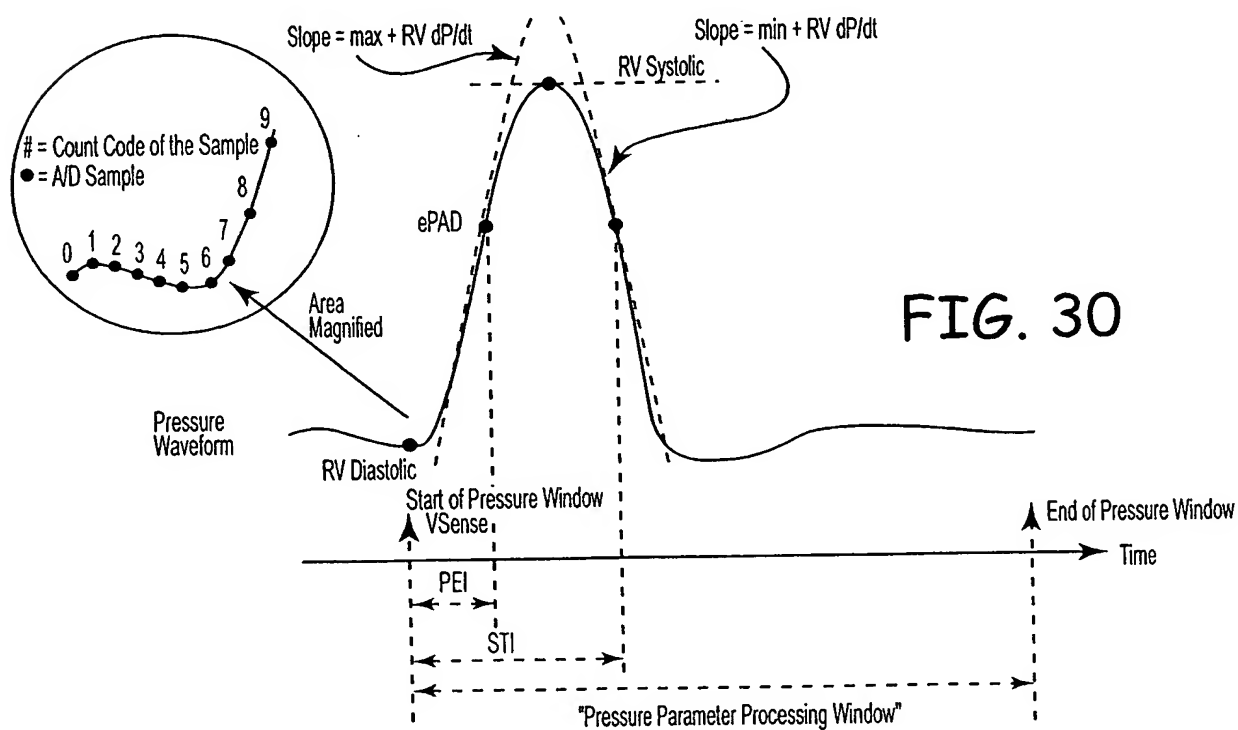


FIG. 30

Command Codes and Measured Parameters

Command Codes	Measured Parameter	Description
Vsense		Command Code that is passed with a trigger down to the sensor. Defines the start of the "Pressure Parameter Processing Window".
End of Pressure Window		Command Code that is passed with a trigger down to the sensor. Defines the end of the "Pressure Parameter Processing Window".
	max + RV dP / dt	Maximum Positive dP/dt within "Pressure Parameter Processing Window".
	min. - RV dP / dt	Minimum Negative dP/dt within "Pressure Parameter Processing Window".
	PEI	Pre-Ejection Interval. Time interval from Vsense Command Code to + RV dP / dt point. Calculated from time stamp deltas of triggers.
	STI	Systolic Time Interval - Time interval from Vsense Command code to - RV dP dt point. Calculated from time stamp deltas of triggers.
	RV Systolic Pressure	Maximum Pressure. Systole is when the heart is squeezing to pump blood.
	RV Diastolic Pressure	Ideally Minimum Pressure but will be defined as pressure measured at Vsense trigger Command Code. Diastole is when the heart is relaxed and is filling with blood.
	RV Pulse Pressure	RV Systolic - RV Diastolic.
	ePAD	Pressure at max + RV dP/dt. ePAD is estimated Pulmonary Artery Diastolic pressure and gives an estimate of a snapshot of left ventricular pressure since the mitral valve is open at this point in time.

FIG. 31

Command Overview

Master Command Name	Command Length Bit Times	Command Usage
Unlocks (00hex)	33	Safety command for master to unlock/lock certain areas of memory or to unmap slaves so they only respond to the long addresses.
Search Long Address (01hex)	26-89 (As search progresses more and more of the long address is added onto the command)	Sends a string of bit(s) representing the long address stretching from MSB towards LSB. If a slave is at that long address and is unmapped then it pulls the DATA line low (i.e. does an ack).
Write Short Address (02hex)	89	Using the long address it assigns a short address
Trigger (03hex)	33	Triggering slaves. Each trigger has an associated Count and Command Code.
Quick Trigger (QT bit Set)	24	Triggering slaves with a command fewer bit time. Each trigger has an associated Count.
Read (04hex)	24 plus data response	Reads RAM/ Register Memory
Read Results (05hex)	33 plus data response	Reads Result (ADC) data out of RAM/Register Memory and has an automatic clear data function and resetting of pointer movement.
Write (06hex)	33	Writes a value into RAM/Register Memory
LSB RAM/REG Address (07hex)	33	Sets LSB portion of Pointer to RAM/Register Address Space
MSB RAM/REG Address (08hex)	33	Sets MSB portion of Pointer to RAM/Register Address Space
LSB EEPROM Address (09hex)	33	Sets LSB portion of Pointer to EEPROM Address Space
MSB EEPROM Address (0Ahex)	33	Sets MSB portion of Pointer to EEPROM Address Space
Copy RAM/REG to EEPROM memory (0Bhex)	33	Copies data from RAM/Register Address Space to EEPROM.
Copy EEPROM to RAM/REG memory (0Chex)	33	Copies data from EEPROM to RAM/Register address space.
Quick read (0Dhex)	33 plus data response	Reads the address pointers for debug. Reads the status by the error code and power monitoring.
Master Command Names 0Ehex thru 1Fhex are unused.		

FIG. 32

Master's Unlocks (00hex) Command

Master	Master2	M3	Master4	Master5	Master6	Master7	Total Bit Times
Start	Slaves Unicast or Broadcast See Table 16	QT	Master Command Name- Unlocks (00hex)	Unlock Key Code	Unlock Key Option	FCS	Stop-AckReq-(N)Ack
2	6	1	5	5	3	8	33
	G ₁ G ₀ A ₃ A ₂ A ₁ A ₀	0					
	If Broadcast then all slaves (mapped or unmapped) listen to this command.						
	If Unicast and not for this slave then go to sleep after Master2.						

FIG. 33

Unlock Key Options

Master	M3	Master4	Master5	Explanation	Notes
Slave(s)	QT	Unlocks (00hex)	Unlock Key Code(1)	Unlock Key Options	
Broadcast Only	0		0011 ₂ (07hex)	000 ₂ - Disallow writing a slave long address (and clock/supply trim) 111 ₂ - Allow writing a slave long address (and clock/supply trim)	(2)
Broadcast Only	0		0001 ₂ (01hex)	000 ₂ - Check for unmapped 001 ₂ - Check for mapped 111 ₂ - Unmap all slaves	(3)
Unicast Only	0		0101 ₂ (0Bhex)	000 ₂ - Disallow copying 111 ₂ - Allow copying	(4)
Unicast Only	0		0110 ₂ (0Chex)	000 ₂ - Disallow copying 111 ₂ - Allow copying	(5)

FIG. 34

Master's Unlocks (00hex) Command

Master1	Master2	M3	Master4	Master5	Master6	Master7	Total Bit Times
Start	Slaves Broadcast	QT	Master Command Name Search Long Address (01hex)	Long Address	FCS	Stop Ackreq (N) Ack	
2	6	1	5	1 to 64 bits	8	3	26 to 89
	G ₁ G ₀ A ₃ A ₂ A ₁ A ₀	0					
	All slaves listen to this command whether mapped or unmapped since this command is Broadcast any slave that is mapped does not acknowledge this command see Table 18 (Example Search). A mapped slave may optionally go to sleep after filed Master 4.						

FIG. 35

Example Search

Step	Slave Long Address Bit Patter (Field Master4) (MSB first)	Slave 1010 response	Slave 1001 response	Found Slave
0	Send out an Unlocks (00hex) command forcing all the slaves to be unmapped. Skip this step if you are just checking for new slaves added.			
1	Send out an Unlocks (00hex) command checking for any unmapped slaves. The command is ACK'd since Slaves 1010 and 1001 will say they are unmapped.			
2	1	ack	ack	
3	11	nak	nak	
4	10	ack	ack	
5	101	ack	nak	
6	1011	nak	nak	
7	1010	ack	nak	1010
8	Send out a Write Short Address (02hex) command to assign 1010 a short address. This will make this slave mapped.			
9	Send out and Unlocks (00hex) command checking for any unmapped slaves. The command is ACK'd since Slave 1001 will say it is unmapped.			
10	1	nak (mapped)	ack	
11	11	nak (mapped)	nak	
12	10	nak (mapped)	ack	
13	101	nak (mapped)	nak	
14	100	nak (mapped)	nak	
15	1001	nak (mapped)	ack	1001
16	Send out a Write Short Address (02hex) command to assign 1001 a short address. This will make this slave mapped.			
17	Send out and Unlocks (00hex) command checking for any unmapped slaves. The command is NAK'd since both slaves 1010 and 1001 are mapped. This tells the master the search for unmapped slaves is completed.			

FIG. 36

Master's Write Short Address (02hex) Command

Master1	Master2						M3	Master4	Master5	Master6	Master7	Total Bit Times
Start	Slaves Unicast						QT	Master Command Name Write Short Address (02hex)	Long Address	FCS	Stop-Ackreq-(N) Ack	
2	6						1	5	64	8	3	89
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
										unmapped Long Address not for this above goes to sleep after Master5		
							Mapped - not for this slave go to sleep after Master2					

FIG. 37

Trigger (03hex) Command

Master1	Master2						M3	Master4			Master5		Master7		Master6	Total Bit Times
Start	Slave(s) Multicast						QT	Master Command Name-Trigger (o3hex)			Count	Command Code	Stop-AckREQ-(N)Ac		FCS	
2	6						1	5			4	4	3		8	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0									
											unmapped - goes to sleep after Master4					
							Mapped - not for this slave go to sleep after Master2									

FIG. 38

Trigger Command Code for cardiac IMD

Trigger Command Code	Code Meaning
0000	RV Pace
0001	RV Sense
0010	RA Pace
0011	RA Sense
0100	LV Pace
0101	LV Sense
0110	LA Pace
0111	LA Sense
1000	unused
1001	unused
...	unused...
1110	no specific Command Code occurring
1111	Cleared Data

FIG. 39

Trigger Command Code for Sonomicrometry

Trigger Command Code	Code Meaning
0000	all listen external acoustic ping
0001	acoustic ping 0 listen 1,2,3,4
0010	acoustic ping 1 listen 0,2,3,4
0011	acoustic ping 2 listen 0,1,3,4
0100	acoustic ping 3 listen 0,1,2,4
0101	acoustic ping 4 listen 0,1,2,3
0110	TBD or error or unused do nothing
0111	TBD or error or unused do nothing
...	TBD or error or unused do nothing
1110	no specific Command Code occurring -don't reconfigure
1111	Cleared Data

FIG. 40

Quick Trigger (QT bit Set) Command

Master1	Master2						M3	Master4	Master5	Master6	Total Bit Times
Start	Slaves						QT	Count	FCS	Stop-AckReq-(N)Ack	
2	6						1	4	8	3	24
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	1				
								unmapped - goes to sleep after Master3			
								Mapped - not for this slave go to sleep after Master2			

FIG. 41

Master's Write Short Address (02hex) Command

Master1	Master2						M3	Master4	Master5	Master6	Master7	Total Bit Times
Start	Slaves Unicast						QT	Master Command Name Read (04hex)	Quantity of bytes 1	FCS	Stop-Ackreq-(N) Ack (Slave Ack Master)	
2	6						1	5	8	8	3	24
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
								unmapped - goes to sleep after Master4				
								Mapped - not for this slave go to sleep after Master2				

FIG. 42

Slave's Read (04hex) Response

msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb
Slave 0	Slave 1	Slave...	Slave x-3	Slave x-2	Slave x-1	Slave x
Data	Data	Data...	Data	Data	FCS	Stop-Stop-Stop
byte 0	byte 1	(multiple bytes)	byte n-2	byte n-1		

FIG. 43

Rules for Read Results (05hex) command

	Read Results (05hex) command is told to read Buffer 0	Read Results (05hex) command is told to read Buffer 1
If ADC Pointer is currently set to write to Buffer 0	<ol style="list-style-type: none"> 1. Set Buffer 1's Count and/or Command Codes to F_{16} codes and have ADC point to top of Buffer 1. Data Result Values of Buffer 1 may or may not be cleared to F codes - this is slave dependent since may want to leave alone to save power. 2. Set Read Result Pointer to Top of Buffer 0. 3. Send up contents of Buffer 0 for quantity of bytes requested. 	<p>(Must be a retry re-read of Buffer 0)</p> <ol style="list-style-type: none"> 1. Continue ADC writing Buffer 0 2. Set Read Result Pointer Top of Buffer 1. 3. Send up contents of Buffer 1 for quantity of bytes requested.
If ADC Pointer is currently set to write to Buffer 1	<p>(Must be a retry re-read of Buffer 0)</p> <ol style="list-style-type: none"> 1. Continue ADC writing Buffer 1. 2. Set Read Result Pointer Top of Buffer 0. 3. Send up contents of Buffer 0 for quantity of bytes requested. 	<ol style="list-style-type: none"> 1. Set Buffer 0's Count and/or Command Codes to F_{16} codes and have ADC point to top of Buffer 0. Data Result Values of Buffer 0 may or may not be cleared to F codes - this is slave dependent since may want to leave alone to save power. 2. Set Read Result Pointer to Top of Buffer 1. 3. Send up contents of Buffer 1 for quantity of bytes requested.

FIG. 44

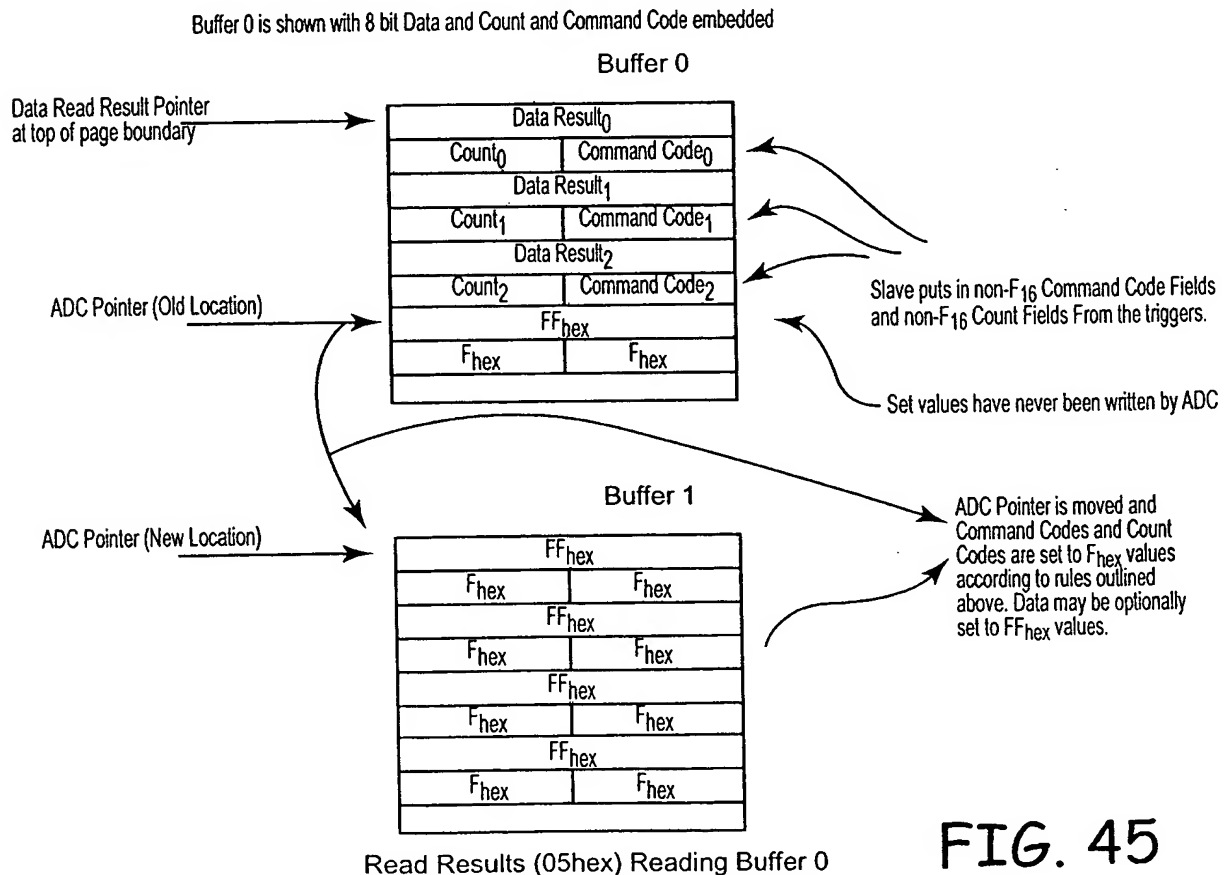


FIG. 45

Master's Read Results (05hex) Command

Master1	Master2						M3	Master4	Master5		M6	Master7	Total Bit Times	
Start	Slave						QT	More Command Name -	Buffer	Quantity of	FCS	Stop-AckREQ(N)Ack		
2	6						1	5	1	7	8	3	33	
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	1							
								unmapped - goes to sleep after Master4						
							Mapped - not for this slave go to sleep after Master2							

FIG. 46

Slave's Read Results (05hex) Example Response

msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	msb...lsb	
Slave 1	Slave 2		Slave...	Slave x-3	Slave x-2		Slave x-1	Slave x
Data ₀	Count ₀	Command Code ₀	(multiple bytes)...	Data _n	Count _n	Command Code _n	FCS	Stop-Stop-Stop

FIG. 47

Master's Write (06hex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast Preferred (Acknowledge will have value)						QT	Master Command Name-White (06hex)	Value Byte to write	FCS	Stop-AckREQ-(N)Ack (slave ACK master)	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
									unmapped - goes to sleep after Master4			
							Mapped - not for this slave go to sleep after Master2					

FIG. 48

Master's LSB RAM/REG Address (07hex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast Preferred (Acknowledge will then have value)						QT	Master Command Name-LSB RAM/REG Address (07hex)	LSB Value	FCS	Stop-AckReq-(N)Ack (slave ACK master)	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
								unmapped - goes to sleep after Master4				
							Mapped - not for this slave go to sleep after Master2					

FIG. 49

Master's MSB RAM/REG Address (08hex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast Preferred (Acknowledge will have value)						QT	Master Command Name- MSB RAM/REG Address (08hex)	MSB Value Byte to write	FCS	Stop-AckREQ-(N)Ack	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
								unmapped - goes to sleep after Master4				
							Mapped - not for this slave go to sleep after Master2					

FIG. 50

Master's LSB EEPROM Address (09hex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast Preferred (Acknowledge will then have value)						QT	Master Command Name- LSB EEPROM Address (09hex)	LSB Value	FCS	Stop-AckREQ(N)Ack	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
									unmapped - goes to sleep after Master4			
							Mapped - not for this slave go to sleep after Master2					

FIG. 51

Master's MSB EEPROM Address (0Ahex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times	
Start	Slave Unicast Preferred (Acknowledge will then have value)						QT	Master Command Name- MSB EEPROM Address (0Ahex)	MSB Value	FCS	Stop-AckREQ-(N)Ack		
2	6						1	5	8	8	3	33	
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0						
								unmapped - goes to sleep after Master4					
							Mapped - not for this slave go to sleep after Master2						

FIG. 52

Master's copy RAM/REG to EEPROM memory (0Bhex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times	
Start	Slave Unicast Preferred (Acknowledge will then have value)						QT	Master Command Name- Copy RAM/REG to EEPROM memory (0Bhex)	Quantity of Bytes 1	FCS	Stop-AckREQ-(N)Ack		
2	6						1	5	8	8	3	33	
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0						
								unmapped - goes to sleep after Master4					
							Mapped - not for this slave go to sleep after Master2						

FIG. 53

Master's copy to EEPROM to RAM/REG Memory (0Chex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast Preferred (Acknowledge will then have value)						QT	Master Command Name-Copy to EEPROM to RAM/REG memory (0Chex)	Quantity of Bytes-1	FCS	Stop-AckReq(N)Ack	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
									unmapped - goes to sleep after Master4			
							Mapped - not for this slave go to sleep after Master2					

FIG. 54

Master's Quick Read (oDhex) Command

Master1	Master2						M3	Master4	Master5	M6	Master7	Total Bit Times
Start	Slave Unicast						QT	Master Command Name-Quick Read (0Dhex)	QRAAddress	FCS	Stop-AckREQ(N)Ack	
2	6						1	5	8	8	3	33
	G ₁	G ₀	A ₃	A ₂	A ₁	A ₀	0					
									unmapped - goes to sleep after Master4			
							Mapped - not for this slave go to sleep after Master2					

FIG. 55

Master's Which Pointer to Read

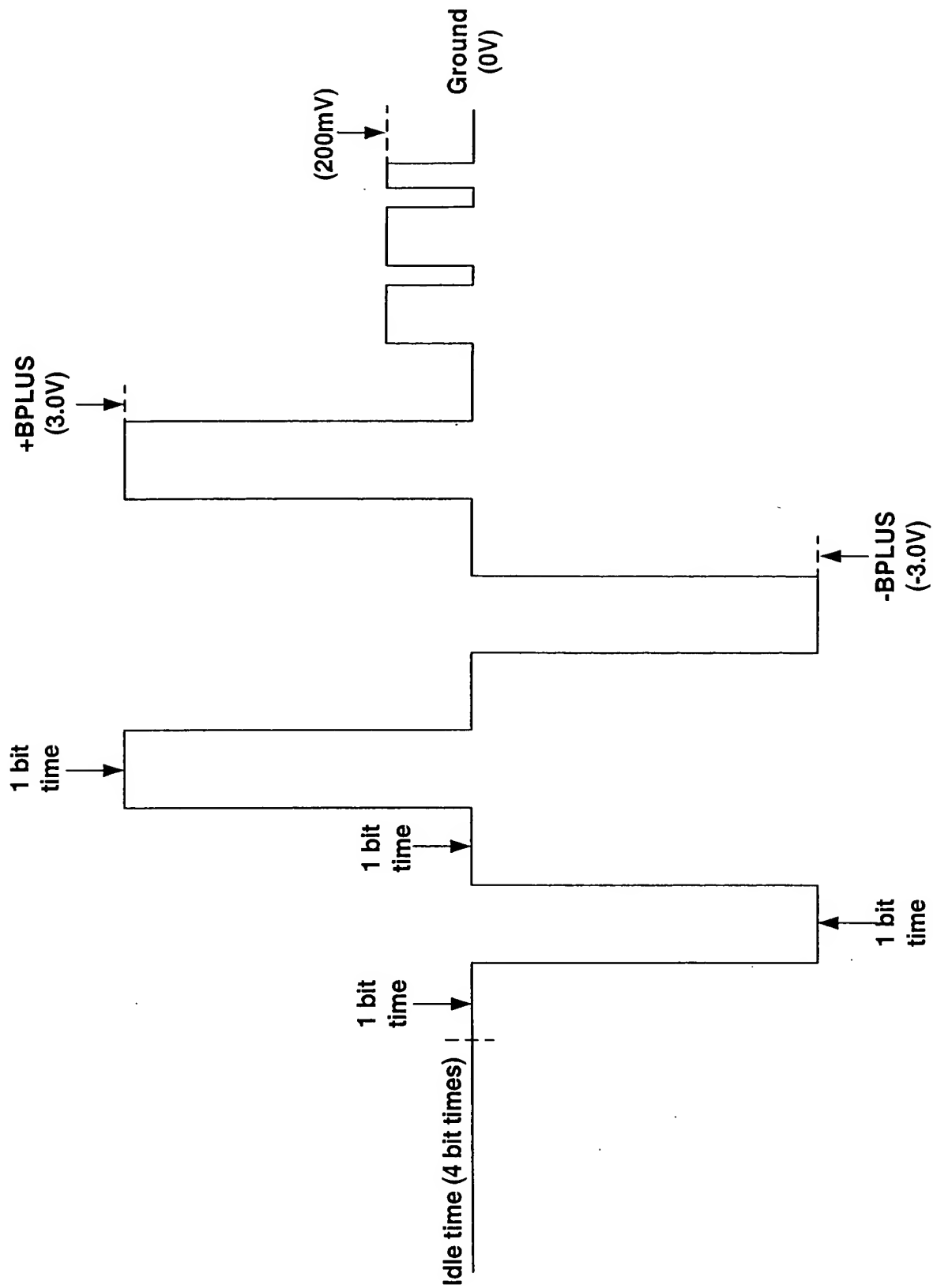
Master5	Description of what it points to
QRAAddress	
00 ₁₆	EEPROM Address Pointer
01 ₁₆	RAM Register Space Address Pointer
02 ₁₆	ADC Address Buffer Pointer
03 ₁₆	Status Word

FIG. 56

Slave's Quick Read (0Dhex) Response

msb...lsb	msb...lsb	msb...lsb	msb...lsb
Slave 1	Slave 2	Slave 3	Slave 4
Data	Data	FCS	Stop-Stop-Stop
MSB	LSB		

FIG. 57



Power and data pulses on two-wire bus

FIG. 58

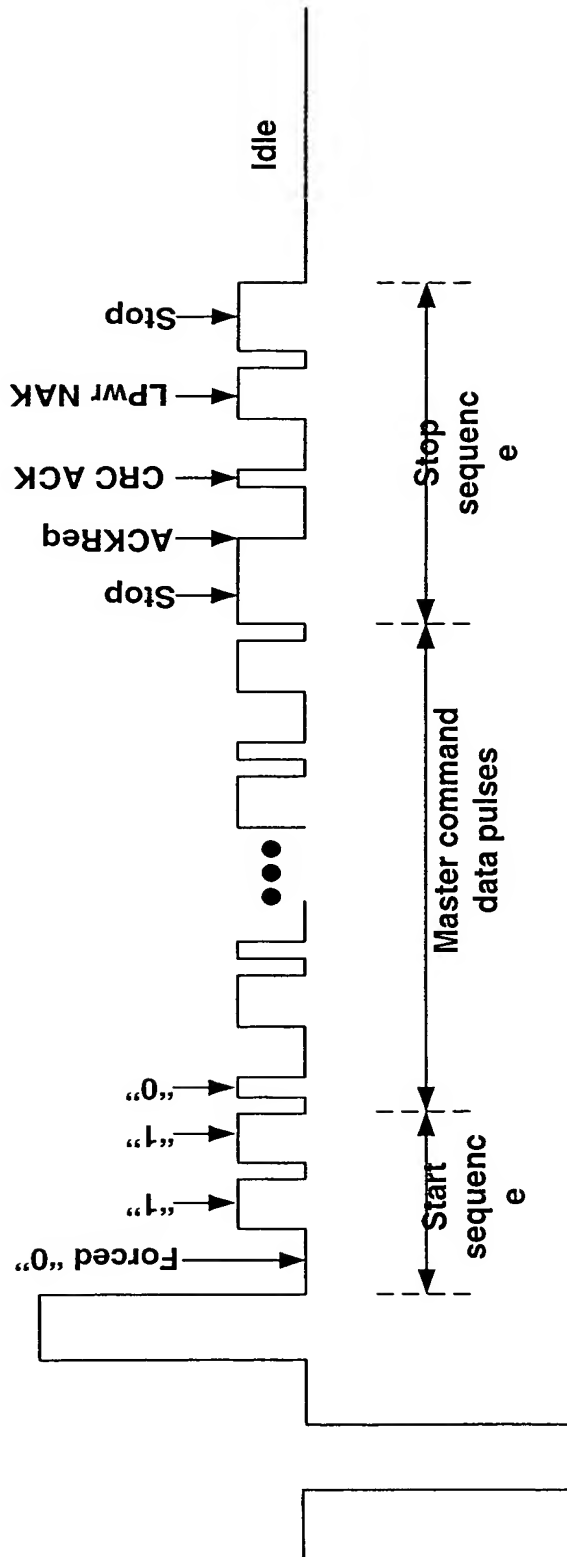


FIG. 59

Example of power and data sequence with Start and Stop sequences

Example of streaming messages

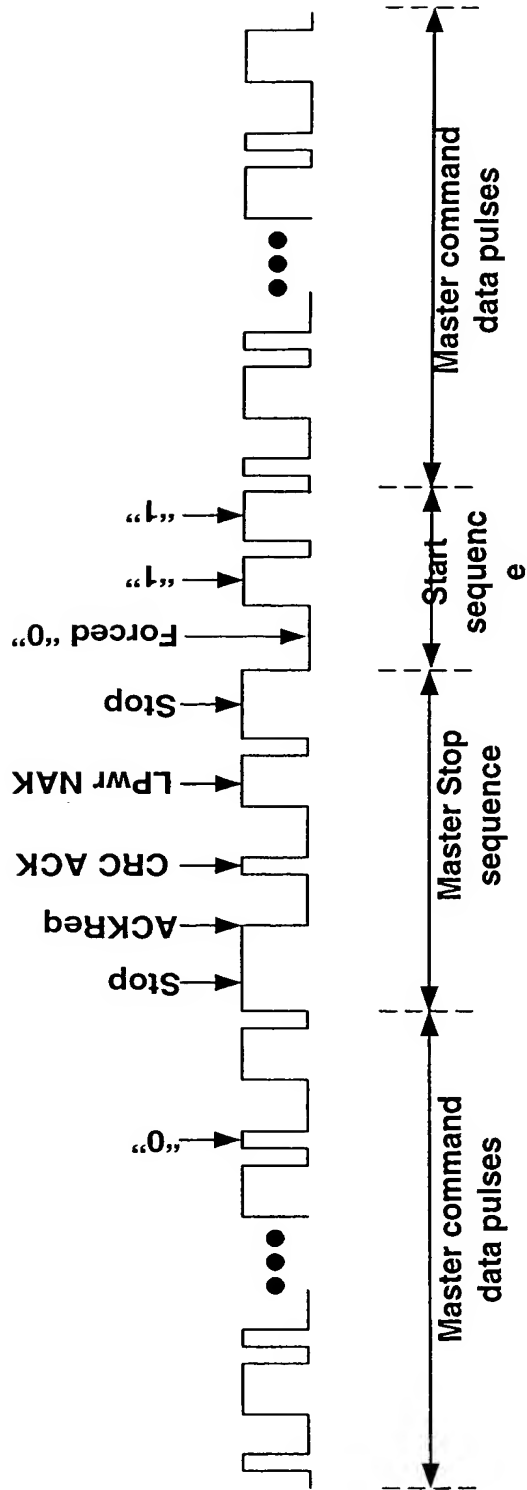


FIG. 60